LASER REPAIRING METHOD OF ELECTROLUMINESCENT DISPLAY DEVICE

BACKGROUND OF THE INVENTION

Field of the Invention:

The invention relates to a laser repairing method of an electroluminescent display device having a plurality of pixels and an electroluminescent element provided in each of the pixels and formed by interposing an electroluminescent layer between an anode layer and a cathode layer.

Description of the Related Art:

An organic electroluminescent (hereafter, referred to as EL) display device using organic EL elements is receiving an attention as a new display device substituted for a CRT or an LCD.

Fig. 5 is a cross-sectional view showing a structure of such an organic EL element. An anode layer 1 made of ITO (indium tin oxide) is formed on a transparent insulating substrate 10 such as a glass substrate, and an organic EL layer formed of a hole transport layer 2, an emissive layer 3, and an electron transport layer 4 is laminated thereon. A cathode layer 5 is formed on this organic EL layer. A potential difference is applied between the anode layer 1 and the cathode layer 5. When a drive current flows in the organic EL element, a hole injected from the anode layer 1 and an electron injected from the cathode layer 5 are recombined in the emissive layer 3, and an organic molecule forming the emissive layer 3 is excited to form an exciton. Light is emitted from the emissive layer 3 in a process of radiation of the exciton and then released outside after going through the transparent anode layer 1 to the transparent insulating substrate 10, thereby completing light-emission.

The above organic EL layer and the cathode layer 5 are formed by a vapor deposition method using a metal mask. In this vapor deposition process, a foreign substance 6 sometimes adheres to a region for the formation of the organic EL element. This generates a short circuit between the anode layer 1 and the cathode layer 5 so that a potential difference disappears

between the anode layer 1 and the cathode layer 5. Then, the drive current does not flow in the organic EL element, and a so-called dark spot occurs in this pixel region.

To solve this problem, laser beams having a predetermined wavelength (for example, 1056 nm) are radiated to the foreign substance 6 to burn it out. This enables normal light-emission at a peripheral pixel region except the pixel irradiated with the laser beams.

However, when the laser beams are not properly radiated to the foreign substance 6, the cathode layer 5 is damaged by the energy of the laser beams and can be torn to form a pin hole at the organic EL element. Once the pin hole is formed, moisture enters the organic EL element therefrom to damage the element, resulting in a display defect of a dark spot.

SUMMARY OF THE INVENTION

The invention provides a method of repairing an electroluminescent display panel using laser. The method includes providing a panel to be assembled into an electroluminescent display device. The panel includes a plurality of pixels each including an electroluminescent element having an electroluminescent layer formed between an anode layer and a cathode layer. The method also includes detecting a foreign substance adhering to the electroluminescent element, and irradiating with a laser beam a region of the display panel that is away from the foreign substance so that a high resistivity region is formed between the anode layer and the cathode layer and around the foreign substance.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of an EL display device of an embodiment of the invention.

Figs. 2A and 2B are cross-sectional views of the EL display device of Fig. 1.

Fig. 3 is a plan view showing a positioning of a laser beam of a repairing method of the EL display device of Fig. 1.

Fig. 4 is a plan view showing a multiple positioning of a laser beam of a repairing method

of the EL display device of Fig. 1.

Fig. 5 is a cross-sectional view of a conventional organic EL element.

Fig. 6 shows a foreign substance adhering to the organic EL element of Fig. 5.

DETAILED DESCRIPTION OF THE INVENTION

An embodiment of the invention will be described with reference to the drawings in detail. An organic EL display device of this embodiment will be described first. Fig. 1 is a plan view showing a pixel of the organic EL display device. Fig. 2A is a cross-sectional view along line A-A of Fig. 1, and Fig. 2B is a cross-sectional view along line B-B of Fig. 1.

As shown in Figs. 1, 2A, and 2B, a pixel 115 is formed in a region enclosed with a gate signal line 51 and a drain signal line 52. A plurality of the pixels 115 is arranged in a matrix configuration.

An organic EL element 60 as a self-emissive element, a switching TFT (thin film transistor) 30 for controlling a timing of supplying an electric current to the organic EL element 60, an organic EL element driving TFT 40 for supplying an electric current to the organic EL element 60, and a storage capacitor 56 are disposed in the pixel 115.

The switching TFT 30 is provided on a periphery of the intersection of the signal lines 51 and 52. A source 33s of the switching TFT 30 serves as a capacitor electrode 55 for forming a capacitor with a storage capacitor electrode line 54 and is connected with a gate electrode 41 of the organic EL element driving TFT 40. A source 43s of the organic EL element driving TFT 40 is connected with the anode layer 61 of the organic EL element 60, while a drain 43d is connected with a driving source line 53 as a current source for the organic EL element 60.

The storage capacitor electrode line 54 is placed in parallel with the gate signal line 51. The storage capacitor electrode line 54 is made of Cr (chromium) and so on and forms a capacitor by storing an electric charge with the capacitor electrode 55 connected to the source

33s of the TFT 30 through a gate insulating film 12. The storage capacitor 56 is provided for storing voltage applied to the gate electrode 41 of the organic EL element driving TFT 40.

The organic EL display device is formed by laminating the TFTs and the organic EL element sequentially on a substrate 10, such as a substrate made of a glass or a synthetic resin, a substrate having conductivity, or a semiconductor substrate. When using a substrate having conductivity or a semiconductor substrate as the substrate 10, however, an insulating film made of SiO_2 or SiN_x is formed on the substrate 10, and then the switching TFT 30, the organic EL element driving TFT 40 and the organic EL element 60 are formed thereon. Each of the TFTs 30 and 40 has a so-called top gate structure in which a gate electrode is placed above an active layer with a gate insulating film being interposed therebetween.

The structure of the switching TFT 30 will be described first.

As shown in Fig. 2A, an amorphous silicon film (hereafter, referred to as an a-Si film) is formed on the insulating substrate 10 made of silica glass or a non-alkali glass by a CVD method and so on. The a-Si film is irradiated with laser beams for melting and recrystalizing to form a poly-silicon film (hereafter, referred to as a p-Si film) as an active layer 33. On the active layer 33, a single-layer or a multi-layer having an SiO_2 film and an SiN_x film is formed as the gate insulating film 12. There are formed on the gate insulating film 12 the gate signal line 51 made of a metal having a high melting point, such as Cr or Mo (molybdenum), and also serving as a gate electrode 31, the drain signal line 52 made of Al (aluminum), and the driving source line 53 made of Al and serving as a driving source of the organic EL element 60.

An interlayer insulating film 15 formed by laminating an SiO_2 film, an SiN_x film and an SiO_2 film covers the whole surfaces of the gate insulating film 12 and the active layer 33. A drain electrode 36 is provided by filling a contact hole provided above the drain 33d with a metal such as Al. Furthermore, a first planarization insulating film 17 for planarizing a surface, which

is made of an organic resin, is formed on the whole surface.

Next, the structure of the organic EL element driving TFT 40 will be described. As shown in Fig. 2B, an active layer 43 formed by poly-crystalizing an a-Si film by irradiating the film by laser beams, the gate insulating film 12, and the gate electrode 41 made of a metal having a high melting point, such as Cr or Mo, are formed sequentially on the insulating substrate 10 made of silica glass, or a non-alkali glass. A channel 43c, a source 43s, and a drain 43d are provided in the active layer 43. The source 43s and the drain 43d are placed on both sides of the channel 43c.

The interlayer insulating film 15 having the SiO_2 film, the SiN_x film and the SiO_2 film is formed on the whole surfaces of the gate insulating film 12 and the active layer 43. The driving source line 53 is connected to a driving source by a contact hole filled with a metal such as Al provided on the drain 43d. Furthermore, a planarization insulating film 17 for planarizing the surface, which is made of, for example, an organic resin is formed on the whole surface. A contact hole is formed in a position corresponding to a source 43s in the planarization insulating film 17. A transparent electrode made of ITO and being in contact with the source 43s through the contact hole, i.e., the anode layer 61 of the organic EL element, is formed on the planarization insulating film 17. The anode layer 61 is formed in each of the pixels as an isolated island.

The organic EL element 60 has a structure of laminating sequentially the anode layer 61 made of a transparent electrode such as ITO, a hole transport layer 62 including a first hole transport layer made of MTDATA (4,4-bis(3-methylphenylphenylamino) biphenyl) and a second hole transport layer made of TPD (4,4,4-tris(3-methylphenylphenylamino)triphenylanine), an emissive layer 63 made of Bebq2 (bis(10-hydroxybenzo[h]quinolinato)beryllium) containing a quinacridone derivative, an electron transport layer 64 made of Bebq2, and a cathode layer 65

made of magnesium-indium alloy, Al or Al alloy.

A second planarization insulating film 66 is formed on the planarization insulating film 17. This second planarization insulating film 66 is patterned to expose the anode layer 61.

In the organic EL element 60, a hole injected from the anode layer 61 and an electron injected from the cathode layer 65 are recombined in the emissive layer 63, and an exciton is formed by exciting an organic module forming the emissive layer 63. Light is emitted from the emissive layer 63 in a process of radiation of the exciton and then released outside after going through the transparent anode layer 61 to the transparent insulating substrate 10, thereby completing light-emission.

Next, a laser repairing method of the above described organic EL display device will be described. As shown in Fig. 3, a foreign substance 100 is now detected adhering to the organic EL element 60 of one pixel. A cross-section of the structure shown in Fig. 3 is similar to that shown in Fig. 6. As a method of detecting a foreign substance, for example, visual observation using a microscope or an automatic detecting method by a foreign substance detecting device can be employed.

In the repairing method of this embodiment, laser beams are configured not to directly incident on the foreign substance 100, but to be incident on an irradiation region 111 near the foreign substance 100. This prevents the organic EL element 60 having the foreign substance 100 from being damaged and thus prevents a pin hole formation. By irradiating with the laser beams the irradiation region 111 at a predetermined distance from the foreign substance 100, the energy of the laser beams spreads concentrically from the irradiating region 111, i.e., the laser beams do not hit the foreign substance 100 directly. Accordingly, the laser energy is supplied to the foreign substance 100 indirectly. This spread of the laser energy forms a high resistivity region 112, shown in Fig. 3, between the anode layer 61 and the cathode layer 65 so that a

defective portion caused by a short circuit by the foreign substance 100 can be repaired. This high resistivity region 112 is formed because the hole transport layer 2, the emissive layer 3 and the electron transport layer 4 in this region 112 are melted together by thermal energy of the laser beams and thus the layered structure thereof disappears.

Here, a commercially available YAG laser (for example, having a laser wavelength of 355 nm) can be used as the laser source. The size of the irradiating region 111 is 5 μ m by 5 μ m, for example. The size of the foreign substance 100 is 0.3 μ m to 10 μ m. It is preferable to set the irradiation region 111 at a distance of 5 μ m to 10 μ m from the foreign substance 100.

When the size of the foreign substance 100 is 3 μ m or more, it is preferable to supply a large amount of energy to the irradiation region 111 by positioning the laser beams to four different peripheral regions of the foreign substance 100, that is, a left side, an upper side, a right side and a lower side (I to IV in Fig. 4) of the foreign substance 100, as shown in Fig. 4. The number of the multiple irradiation can be increased or decreased as appropriate based on the size of the foreign substance 100.

In this embodiment, the laser beams having a wavelength of 532 nm or lower can repair the defective portion without damaging the organic EL element.